Rotorcraft Vision

International Powered Lift Conference
Co-sponsored by AHS, AIAA, SAE, RaeS
October 30 - November 1, 2000
Hyatt Regency Crystal City
Arlington, Virginia

AHS INTERNATIONAL

AIAA
American Institute of Aeronautics and Astronautics

SAE AEROSPACE

ROYAL AERONAUTICAL SOCIETY

Dr. John J. Coy
Rotorcraft Program Manager
NASA Ames Research Center
Moffett Field, CA, 94035
Tel: 650-604-3122
Email: jcoy@mail.arc.nasa.gov

Features of the Future World Environment

- *High time value for travelers and goods*
- *Demand for rapid, reliable transport*
- *Increasing urban/suburban land value*
- *Demand for routine access to remote areas*
- *Requirements for robust military systems*
- *Opportunities for advanced technologies*

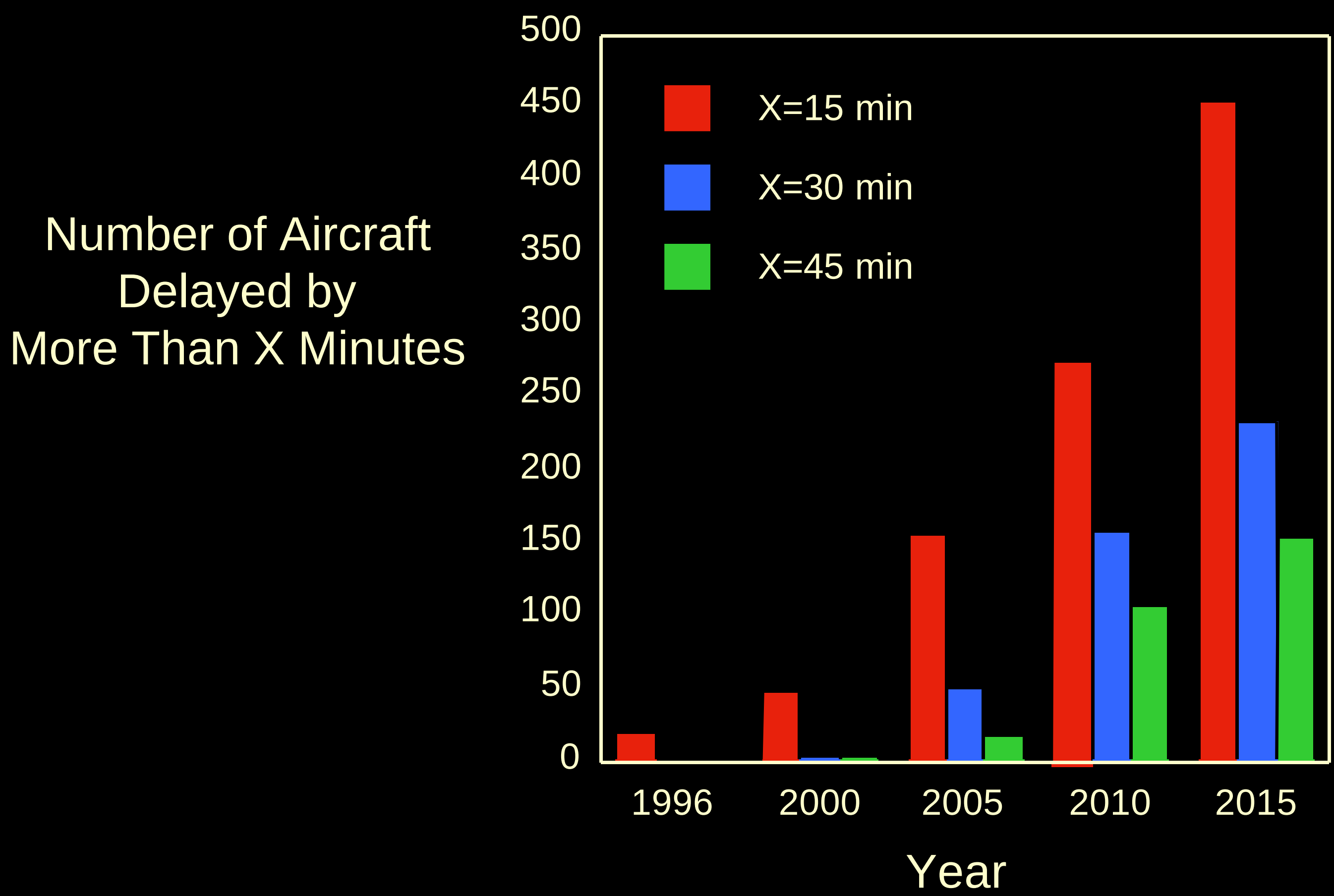
The Transportation Dilemma

- **Road transport is no longer a candidate**
  - *Requires valuable land in urban areas*
  - *High capital cost*
  - *Not a high-speed or long-distance solution*
  - *Adverse environmental impact*

- **Rail offers just a partial solution**
  - *Inflexible routes, high capital cost, topographical constraints*
  - *Cost effective only at high traffic densities*
  - *Competes with other uses for land*
- **Fixed-wing air capacity is severely limited by need for runways**
  - *Runway capacity is the bottleneck*
  - *New runways are costly, require valuable land, raise environmental concerns, and have long lead times*
  - *Urban and suburban airports (DCA, LGA, SFO, SJC, MIA, LAX, etc.) will be under great pressure to relocate*

Flight Delays Will Worsen Without Corrective Action

Predicted Delay Increase at a Major Hub Airport
Based on MITRE DPAT Model



Single day, good weather
Single airport, major hub
Total landings
1996: 997
2000: 1,378
2005: 1,576
2010: 1,776
2015: 1,910

Source: Donohue, G., “Investing in Air Transportation Research,” *Aerospace America*, Sept. 2000, pp. 28-31

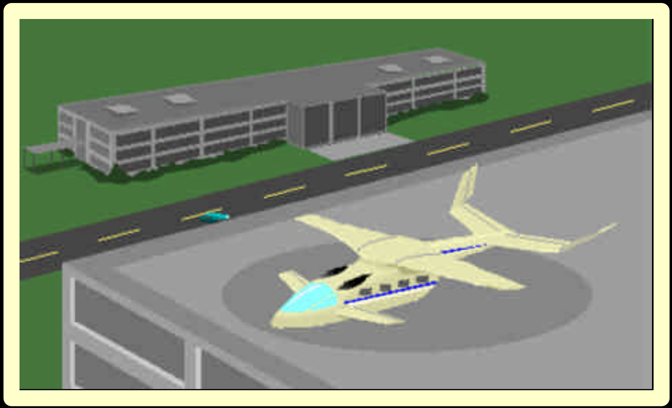
Future Rotorcraft Vision

A mix of *vertical lift air vehicles*

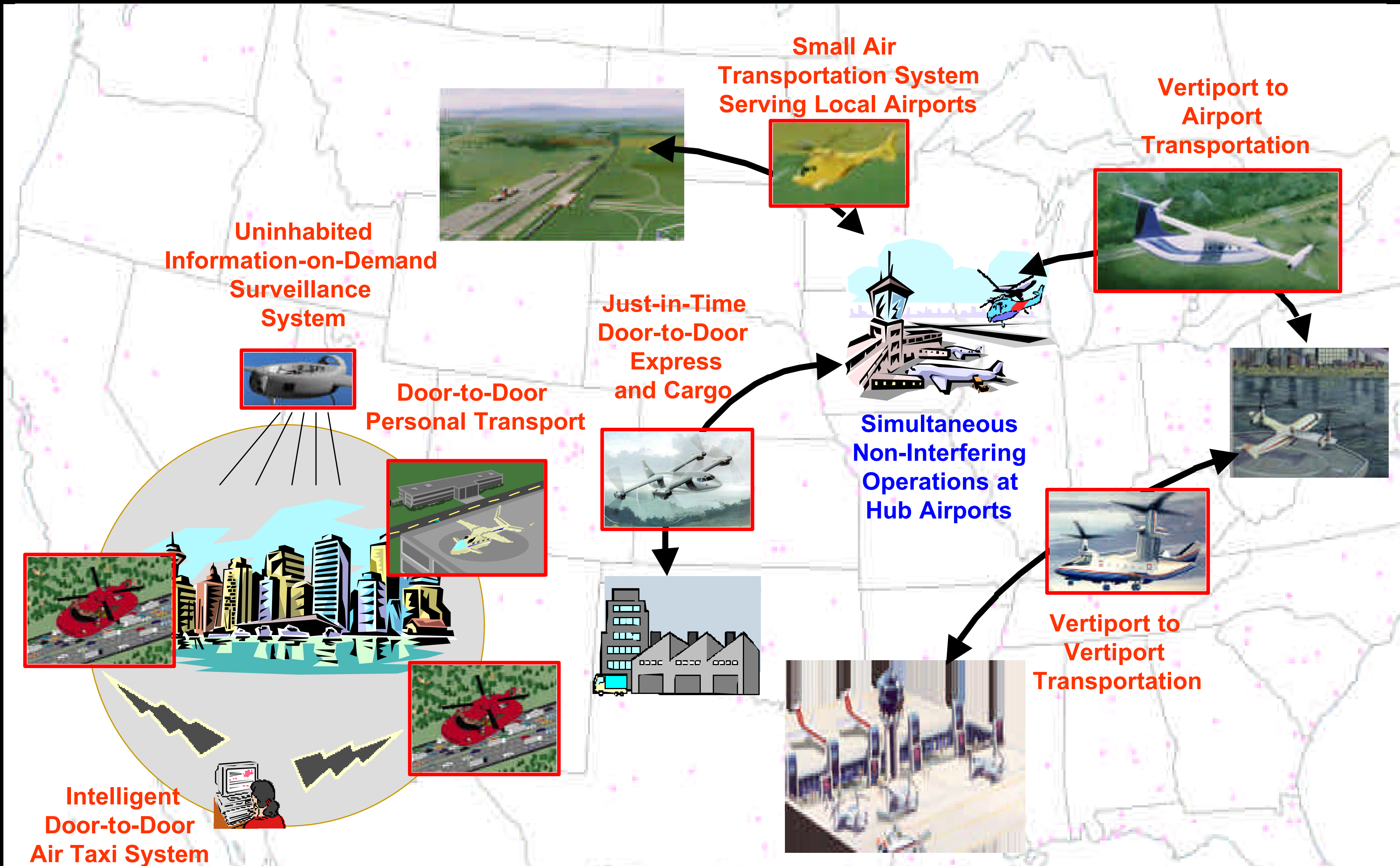
operating within a *three-dimensional grid*

will *revolutionize* air transportation mobility:

- ✓ True point-to-point or door-to-door transport
- ✓ Complete flexibility of origin and destination
- ✓ No need for extensive real estate or large infrastructure investment
- ✓ No constraints on system throughput dictated by the need for runways



Rotorcraft Vision



Runway Independent Aircraft Operations

Increases airport throughput by 25% and reduces delays at airports

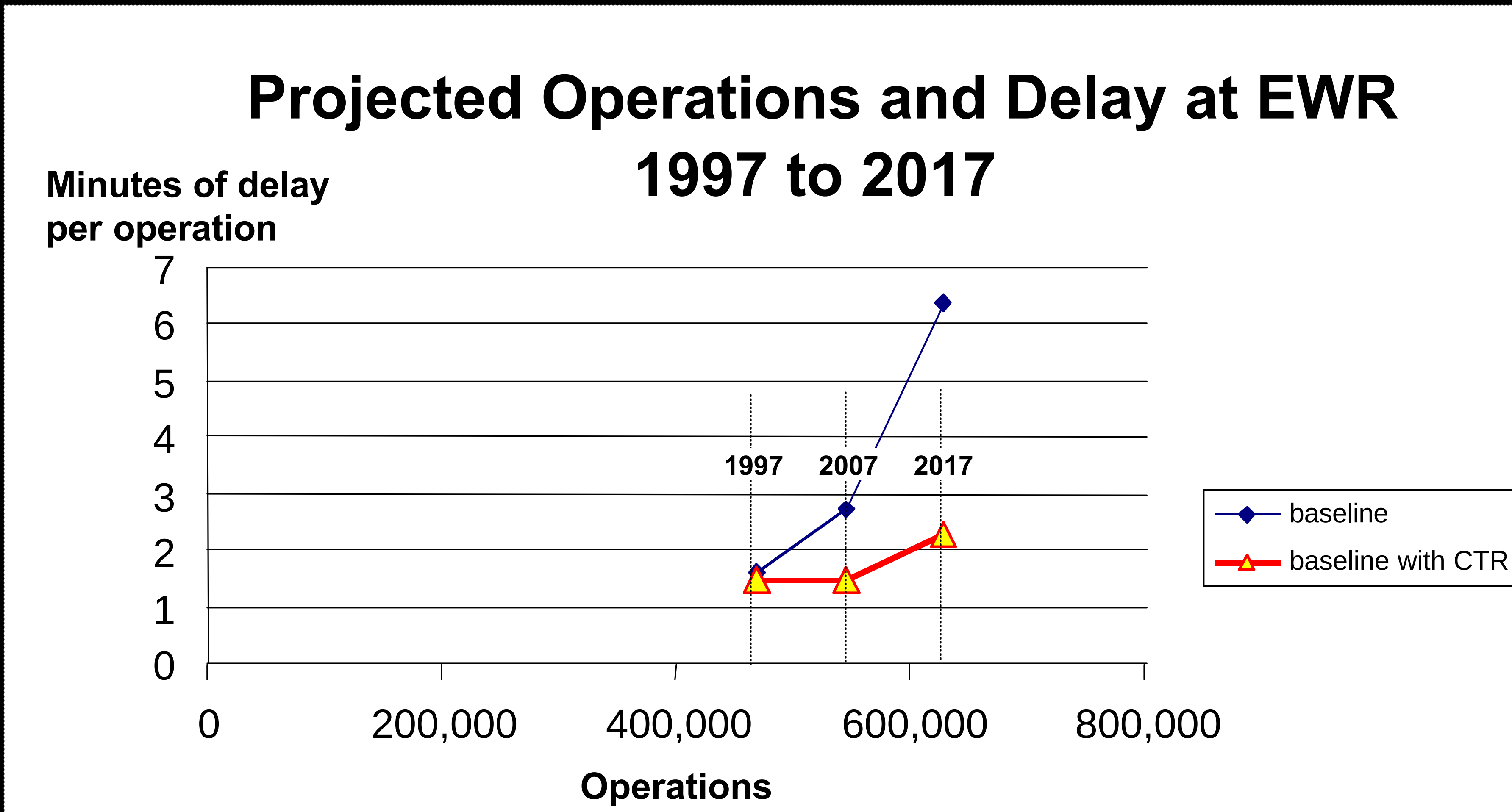
- **Provides 50% as much delay reduction as a new runway**

Improves terminal area airspace safety and reliability

- **Separate corridors and runway traffic for slower aircraft and jet transports**
- **Improved separation in departure corridors**

Commuter fixed wing aircraft (< 300 nm) carry 20% of the passengers, yet account for 40% of the departures at major hub airports

Benefit of Runway Independent Operations



Source: Civil Tiltrotor (CTR) Feasibility Study - Impact at EWR

Runway-Independent Rotorcraft Can Increase System Throughput by 25% or More

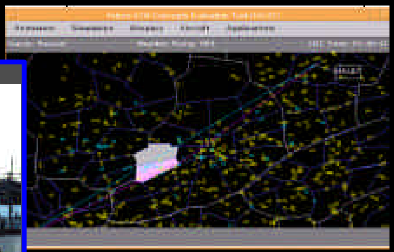
Eliminating runway use for short-haul travel increases capacity by 25%

Simultaneous Non-Interfering Operations for trips under 300 miles enable 30% throughput increase at hubs that account for 80% of traffic

AvSTAR
(Aviation Systems Technology Advanced Research)

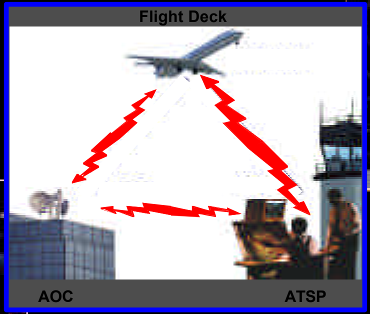
Enabling Tomorrow's Air Transportation System

Improved traffic flow management



National Traffic Flow Management

Remove restrictions across facility/sector boundaries



Reduce separation in the terminal area

Integrated Airspace Decision Support Tools

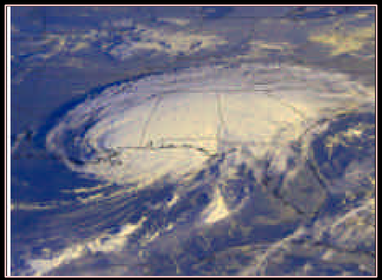
Eliminate surface congestion

Surface Congestion Alleviation

Runway Productivity

Arrival/Departure Decision Support Tools

Runway Independent Aircraft Operations



ATM/TFM Weather Integration

Rotorcraft Can Sharply Reduce Door-to-Door Time

Airport to Airport (Fixed Wing)

30 miles @ 45 mph ***40 min.***

Departure ***5 min.***

Check-in ***45 min.***

200 miles @ 400 mph ***30 min.***

Approach & landing ***5 min.***

Mode change ***20 min.***

30 miles @ 45 mph ***40 min.***

Total trip time

200 miles: 185 min.

300 miles: 200 min.

+ Delay

GA Airport/Vertiport to GA Airport/Vertiport (Helicopter)

15 miles @ 45 mph ***20 min.***

Departure 2 min.

Check-in ***15 min.***

200 miles @ 200 mph ***60 min.***

Approach & landing ***3 min.***

Mode change ***10 min.***

15 miles @ 45 mph ***20 min.***

Total trip time

200 miles: 130 min.

300 miles: 160 min.

GA Airport/Vertiport to GA Airport/Vertiport (Tiltrotor)

15 miles @ 45 mph ***20 min.***

Departure ***2 min.***

Check-in ***15 min.***

200 miles @ 300 mph ***40 min.***

Approach & landing ***3 min.***

Mode change ***10 min.***

15 miles @ 45 mph ***20 min.***

Total trip time

200 miles: 110 min.

300 miles: 130 min.

Barriers to Achieving the Vision

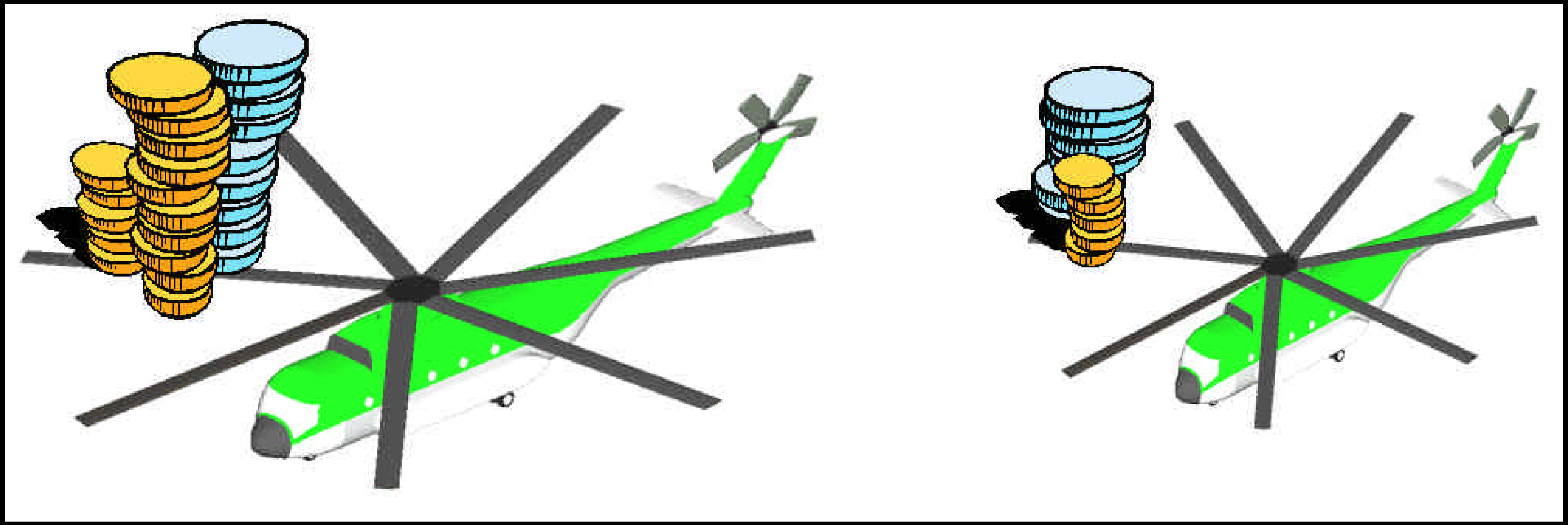
Key Inhibitors to Expanded Rotorcraft Applications:

- Cost per Seat-Mile or Ton-Mile
- Community Acceptance
- Reliable All-Weather Service
- Perceived Safety
- Passenger Acceptance (Ride Comfort, Speed, etc.)
- Piloting Skill Required
- Infrastructure for 3-D Grid Operation

Effects of Technology Improvement

U.S. Army Future Transport Rotorcraft
20-ton Payload, 300-mile Mission Radius

	1994	2005
Gross Weight:	126 tons	62 tons (-51%)
Unit Flyaway Cost:	$186 mil.	$74 mil. (-61%)



Effects of Technology Improvement

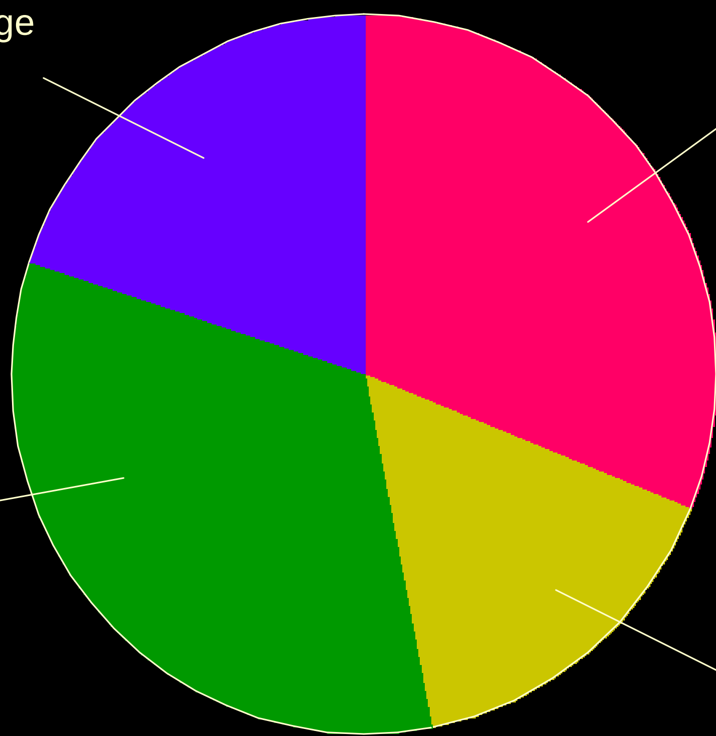
Future Transport Helicopter

Percent gross weight/cost reduction by source

1994 - 2005

- Reduction ratios per stage
- Power-to-weight ratio
- Operating/overhaul cost

- Aeromechanics: 31%
- Hover efficiency
- Propulsive efficiency
- Vehicle drag
- Predictive design tools
- Vibratory loads



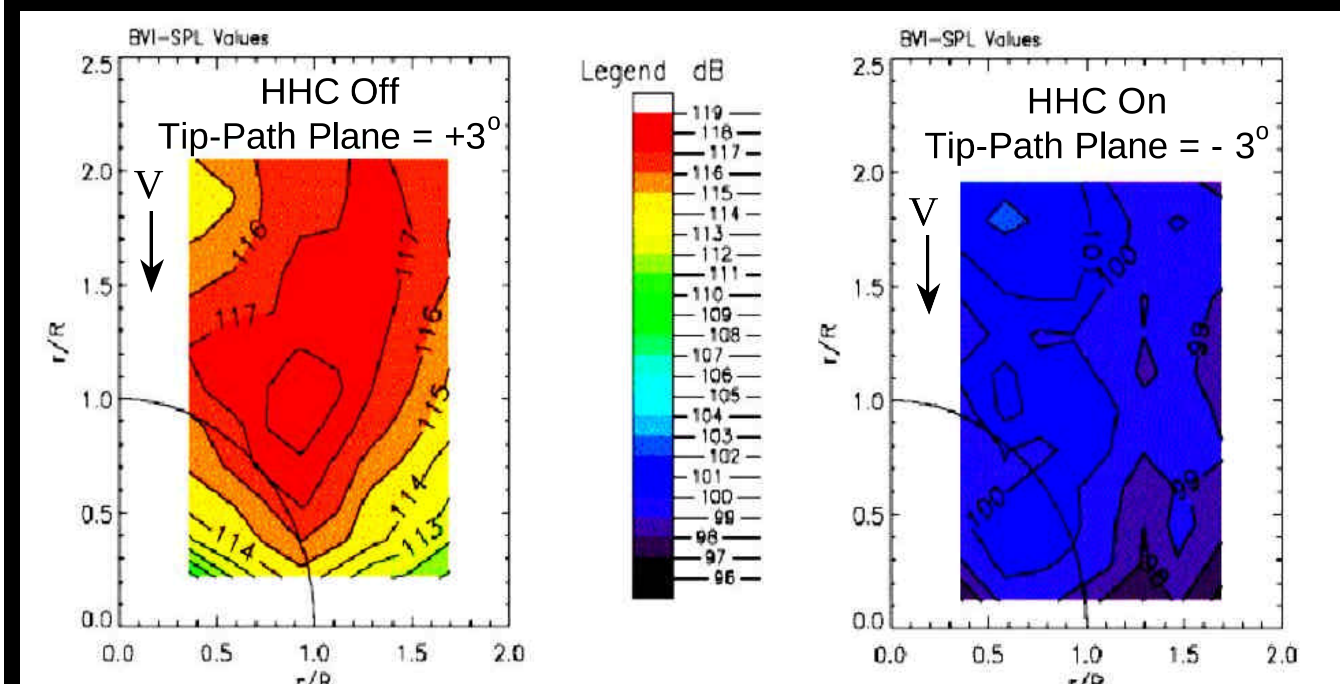
- Fuel consumption
- Contingency ratings
- Power-to-weight ratio
- Operating/overhaul cost

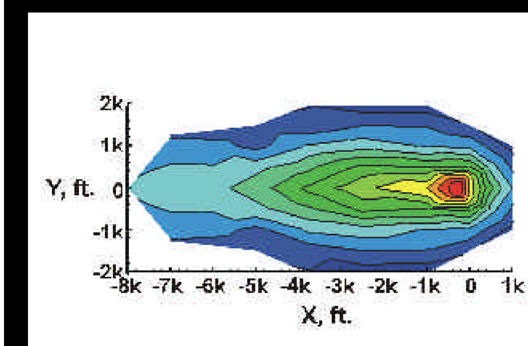
- Weight reduction
- Advanced materials
- Design optimization tools
- Manufacturing cost

Tiltrotor Noise Reduction Breakthroughs

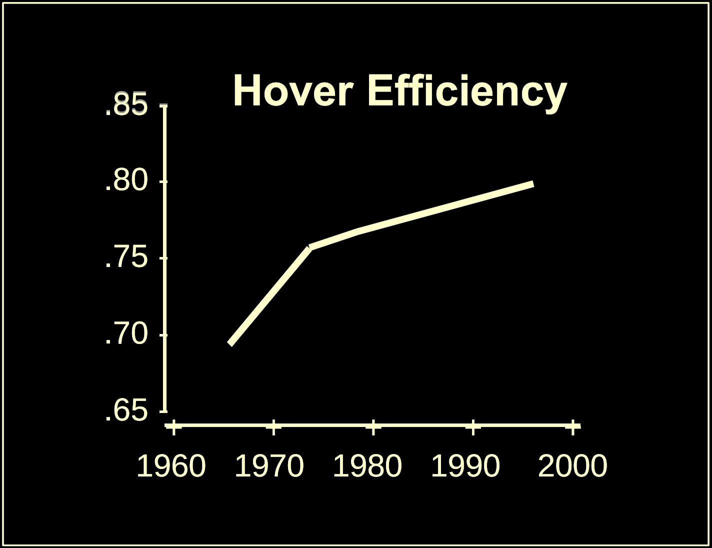
Typical reductions of 12.5 dB demonstrated in wind tunnel tests

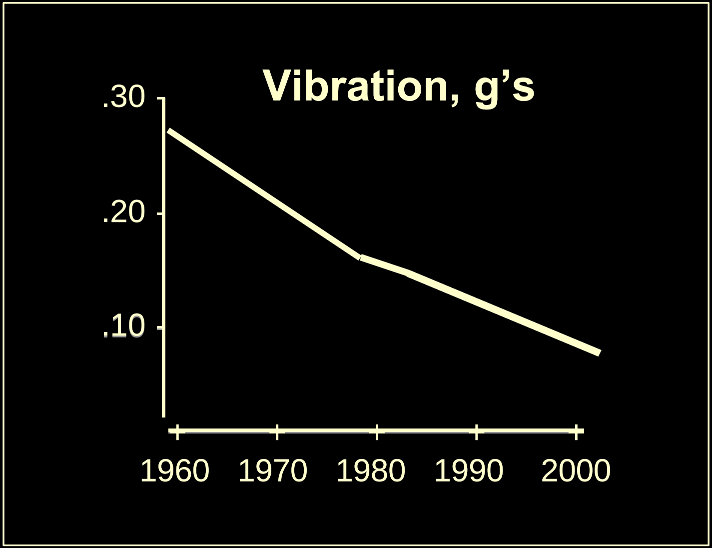
Low-noise approach profiles reduce noise footprint

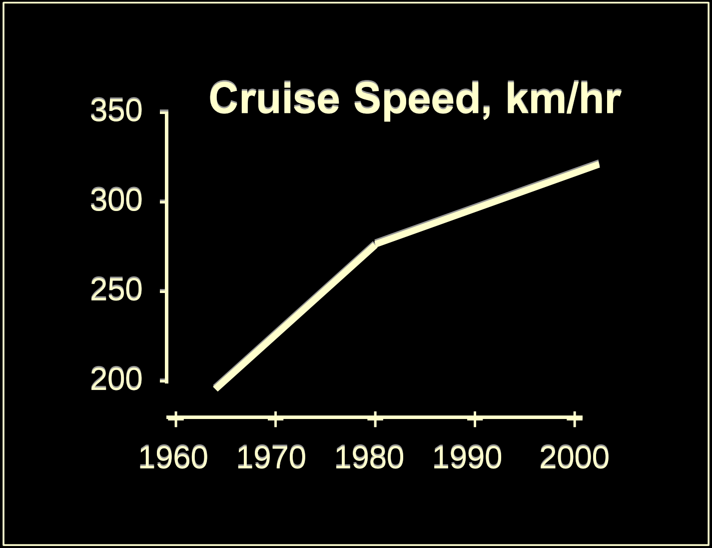


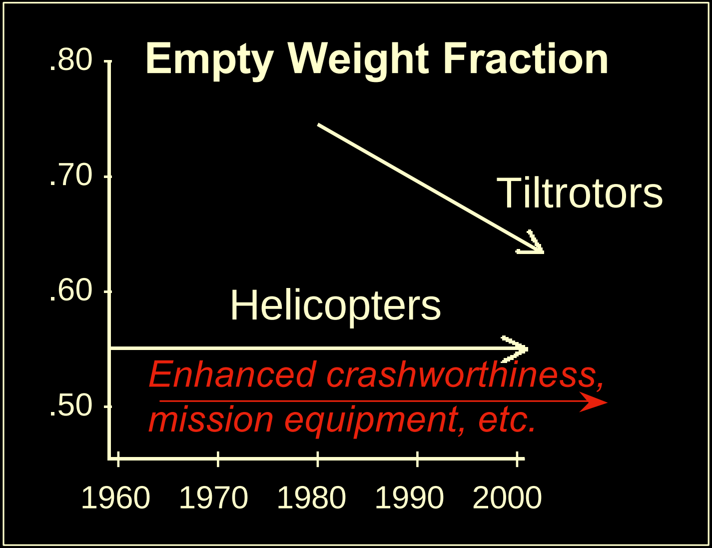


Rotorcraft Technology Trends









Long-Range Technology Goals

ATTRIBUTE	CURRENT LEVEL	2022 TARGET
Vehicle Efficiency	Hover Efficiency = 0.78	0.87
	L/D x Prop. Efficiency = 7 at V_{cruise}	13 at V_{cruise}
	EW Fraction = .55 (helo) -.62 (tiltrotor)	30% reduction
Cruise Speed	Helicopter = 170 kts	200 kts
	Tiltrotor = 250 kts	Advanced Config. = 350 - 400 kts
External Noise	External noise metric TBD	Below annoyance threshold
Vibration & Internal Noise	.05g vibration	Imperceptible (.005g)
Intelligent Automation & Cockpit Integration	Pilot aiding	Operator "directs" vehicle
	Autonomous flight (UAV)	Autonomous mission optimization
Reliability & Safety	Reliability metric TBD	Equivalent to fixed-wing airliners
	Accident rate comparable to General Aviation	Equivalent to fixed-wing airliners
All-Weather Operability	IFR-capable	Fully autonomous zero-zero
	Limited icing capability	No restrictions due to icing

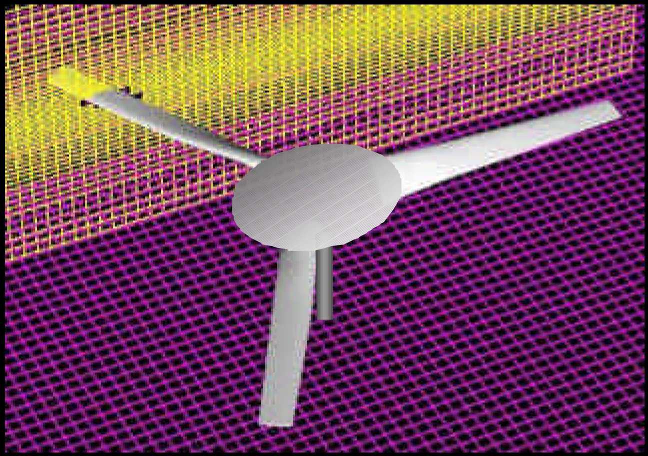
Advanced Rotor/Drive System Concepts

Continuous control of shape and airflow achieves near-ideal performance

Smart material "morphing" blade geometry

Active blowing and boundary layer modification

Swashplate-less control



Active vibration and noise control

Low-noise geometry

Lightweight rotor construction

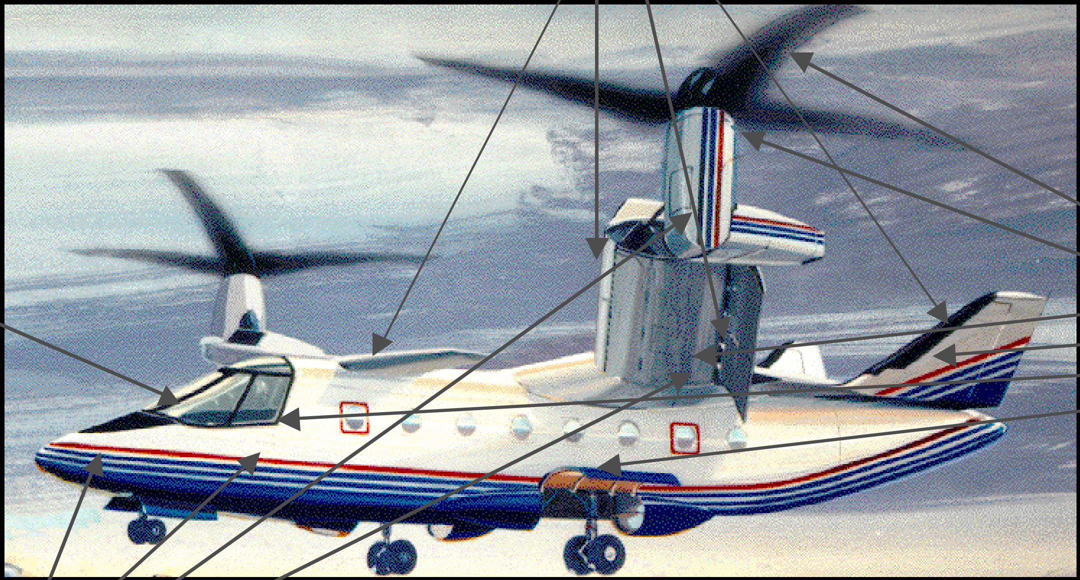
Super-safe rotor and drive shaft

Reverse velocity airfoils

Variable speed, intelligent, self-reconfigurable drive system

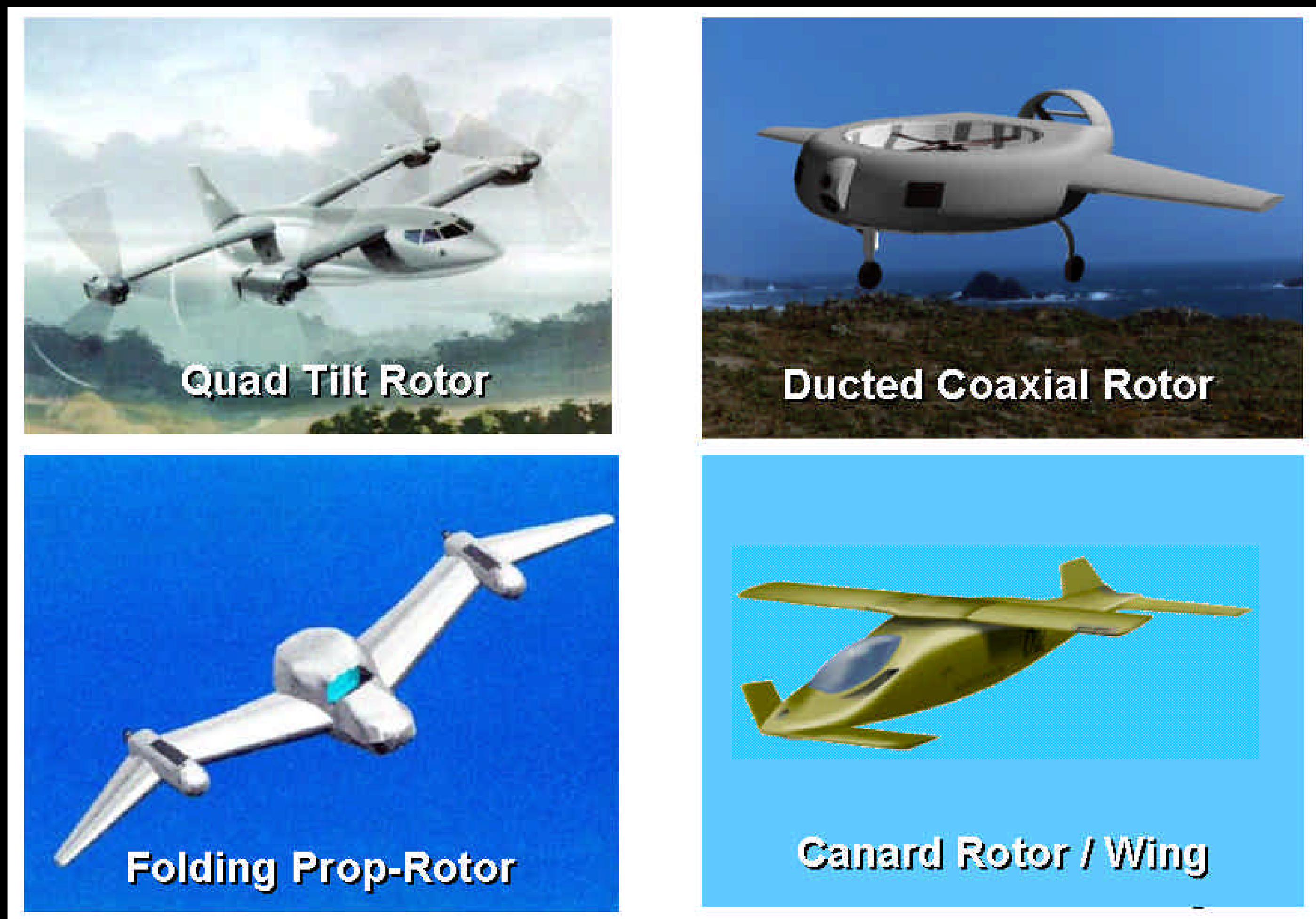
Bio-Analogous Distributed Systems

Distributed sensors, processors, and actuation devices tailor drag and lift, counter vibration, diagnose faults, and implement corrective action



Advanced Vehicle Configurations

High speed enhances productivity of piloted and uninhabited rotorcraft



Personal Transport "Crashproof" Rotorcraft

UAV technology and smart systems enhance safety and reliability

Environmentally friendly

- *Low-noise rotor*

Economical

- *Low-cost construction*
- *Affordable propulsion system*

Safe and easy to operate

- *Smart autonomous self-reconfigurable control system*
- *Super-safe health & usage monitoring and advanced diagnostics*

High Payoff Research Topics Have Robust Potential

INNOVATIVE TECHNOLOGIES

ATTRIBUTES

	Intelligent Rotorcraft Systems	Efficient Active Rotor	Revolutionary Configurations
Vehicle Efficiency	**X**	**X**	**X**
Cruise Speed	x	**X**	**X**
External Noise	**X**	**X**	x
Vibration & Internal Noise	**X**	**X**	x
Intelligent Automation & Cockpit Integration	**X**		x
Design for Reliability & Safety	**X**	x	x
All-Weather Operability	**X**		

X Primary influence
x Secondary influence

Conclusions

- Meeting 21st Century air transport needs represents a significant growth opportunity for the rotorcraft community
- Rotorcraft can play a key role in the air transportation system of the future …
- *… if* they can achieve competitive ticket cost, community acceptance, and passenger comfort
- Rotorcraft have improved on many fronts, but the technology is still maturing
- A strong research effort will be needed to meet NASA, DoD, and industry goals